RESEARCH MANAGEMENT

A PUBLICATION OF THE
INDUSTRIAL RESEARCH INSTITUTE

WINTER 1958
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ABOUT THIS ISSUE

The keynote address at the Fall Meeting of the Industrial Research Institute, held at the Shoreham Hotel in Washington, D.C., October 19–22, 1958, was delivered by President Eisenhower's Special Assistant for Science and Technology, Dr. James R. Killian. We are honored to be able to bring to our readers the text of Dr. Killian's stirring address, "Achieving Concert Pitch in Our National Science Program." Dr. Killian is on leave from Massachusetts Institute of Technology to serve the government. He became President of M.I.T., his alma mater, in 1948 and recently was made Chairman of the Board.

Three other articles in this issue are taken from the program of the Fall I.R.I. Meeting. Two of these comprised a session on "The Research Supervisor." They present contrasting views of this subject: first, those of the young research worker, in the panel discussion entitled "The Research Chemist Looks at Supervision"; and second, those of the senior research executive, in the paper entitled, "The Responsibilities of the First Line of Supervision in Research."

The panel of young chemists from the research laboratory of the Hercules Powder Co., Drs. Dwight C. Lincoln, E. J. Vandenberg, Leo J. Filar, D. R. Levering, John D. Floyd, Robert F. Goddu, and John F. Walker, are introduced by Dr. Peter Van Wyck, Director of the Hercules Research Center. These panelists, called "Young Turks" because of their energetic urge to progress, were in the lowest professional job classification when the panel discussion was first presented at Hercules last spring, but since then two of them have been promoted to the rank of Senior Chemist. The text of the article is just as these young men wrote it—no one

would wish to risk dulling its discrimination by proposing changes. It is not often that one can read such frank and intelligent comment from the rank and file in the laboratory.

The senior executive's point of view is expressed in the paper by Dr. James Hillier, Vice President, RCA Laboratories, Radio Corporation of America. This article had its origin in a series of meetings of small groups of research directors organized by the I.R.I. last winter to explore the value of such meetings in advancing the art of research management. The subject chosen for these exploratory meetings was "The Responsibilities of the First Line of Supervision in Research." Although these meetings did not develop much of a concensus, the discussions did provide the stimulus without which Dr. Hillier might not have written the article which we here present. Dr. Hillier has been with RCA since 1940 except for the interval 1953–54 when he was with Melpar, Inc. In 1957 he became General Manager of RCA Laboratories and about a year later he was elected Vice President. As a scientist, he is best known for the leading part he has taken in the development and application of the RCA electron microscope.

The fourth article taken from the program of the Fall I.R.I. Meeting comes from a session on the subject "New Scientific Frontiers." It is a review of what the research director ought to know about the rapidly developing subject of solar energy utilization. The author is Dr. George O. G. Löf, a consultant and former professor of chemical engineering at the University of Colorado and at the University of Denver.

This issue concludes with an article on the subject "Make-or-Buy Decisions" by Dr. Maurice Nelles, Vice President, Crane Company. This discussion was originally presented at an American Management Association Special Conference, "How to Capitalize on Research and Engineering Talent," at Pasadena, California, on May 7, 1958. Dr. Nelles has been with Crane Company since 1957; previously he directed research at Borg-Warner Corporation and at Technicolor Corporation.

ACHIEVING CONCERT PITCH IN OUR NATIONAL SCIENCE PROGRAM*

J. R. KILLIAN, JR.

Special Assistant for Science and Technology to the President of the United States, Washington, D.C.

Your hospitality affords me an opportunity to report briefly on some recent and current moves to advance the Nation's science program. During the past year President Eisenhower has opened new channels of communication between the White House and the Nation's scientific and engineering communities, and he has introduced or stimulated numerous measures to underwrite U.S. leadership in science and engineering. Among the actions taken by the President was the appointment of a Special Assistant for Science and Technology, supported by a reconstituted President's Science Advisory Committee. I wish to speak particularly of the work and program of my office and the Science Advisory Committee.

I

In carrying on its work for the President, the Science Advisory Committee is organized into 15 panels which include both regular Committee members and other engineers and scientists selected from outside the ranks of the Committee. In recruiting these panels, the policy has been to select the best qualified scientists and

* Address delivered at a dinner meeting of the Industrial Research Institute, Shoreham Hotel, Washington, D.C., October 21, 1958.

engineers we can find in the country and draw upon their special competence and experience in tackling the problems confronting us.

The Committee serves as a Board of Directors or consultants to me as Special Assistant to the President. It has the prerogative, when it chooses, to report directly to the President. As Special Assistant, I also have—in addition to the Advisory Committee and its panels—special consultants, task forces, and staff which are dealing with problems of considerable urgency. Both the Committee and I are fortunate in having an exceptionally capable staff to assist us in our work. At the present time, the Science Advisory Committee and my office have over fifty scientists and engineers at work.

In bringing together this representative and able group, we have had very heartening evidence of the sense of urgency and public responsibility of the American scientific and engineering community. Many members of both these professions have readily and generously made themselves available, and others, let me emphasize, will be called to help in the future.

There has been, apparently, a misconception abroad that my office and the Science Advisory Committee have operating responsibilities in government. We do not. We have no operational responsibility, for example, for the development of missiles or satellites. We have, of course, made intensive studies of various aspects of our missile and space programs for the information and use of the President. My function and that of the Committee is to provide answers to questions raised by the President, to undertake assignments for him of an advisory kind, to mobilize the best scientific advice of the country, and to make recommendations to him in regard to ways by which U.S. science and technology can be advanced, especially in regard to ways they can be advanced by the Federal Government and on how they can best serve the nation's security and welfare. This advisory service, the President has indicated, is available also to members of the Cabinet and other officers of the government when they wish it.

It is important also to note that the Special Assistant for Science and Technology is invited to sit in on the meetings of the National Security Council and of the Cabinet and, when appropriate or requested, to present the views and findings of the Science Advisory Committee. The President has thus created a mechanism to bring objective scientific and engineering advice to the top level of government in a manner that reaches across all agencies and departments of government and yet can serve each of them.

In creating this new post and in revitalizing the Science Advisory Committee, widening its scope and associating it with the White House, the President has given special recognition to the fact that science and technology, apart from their use in solving specific problems, have a direct and creative impact on the formulation of public policy. The reconstitution of the Science Advisory Committee in the White House, the intensification of its work, and the establishment of my office have stimulated an extraordinary array of requests within government to make scientific advice available. The problem has been to avoid being overwhelmed by the many requests for advisory services, while at the same time trying to respond helpfully and promptly whenever a need exists. Of the many kinds of requests which come to us, one of the most important and frequent are requests to assist in finding and recruiting able senior personnel to serve the government in some of its top level posts involved with science and engineering.

In addition to the many requests from within the government, there has also been a heartening response from outside of government. More and more our offices serve as a central rallying point and communications center for the civilian scientific community. Your suggestions and comments will be welcome; we need to mobilize the best judgment and experience in the country if we are to make steady headway in strengthening U.S. science and technology.

II

Turning now to the substantive work of the Science Advisory Committee and its Panels, let me list the following five examples:

First, we have a very active panel on science and technology in foreign affairs. It is a source of advice on the role of science and technology in supporting our foreign policy objectives. It seeks to assist government departments and agencies in using science and engineering effectively in our foreign programs, and in furthering international cooperation in science and technology.

As members of a "fraternal community of specialists," scientists and engineers have special advantages and opportunities to assist in achieving international cooperation and agreement. Witness the remarkable record of the International Geophysical Year and its sponsoring agency, the International Congress of Scientific Unions.

In the unrelenting competition which faces the entire free world, nothing less than the full and efficient use of the free world's scientific resources will provide the strength it needs. The full development of science and technology by the free world is essential to its economic and military strength and thus to its political and cultural stability and advance. This is why the achievement of better exchange and cooperation is so important.

Second, the Panel on Scientific Information is now completing a study of the responsibilities of the Federal Government in coordinating the nation's efforts in acquiring, publishing, translating, abstracting, storing, retrieving, and disseminating scientific and technical information. Our progress in science is dependent upon the free and rapid flow of information, for the rate of scientific advance is determined in a large measure by the speed with which research findings are disseminated among investigators who can use them in further research.

Third, the Panel on Space Science took the lead last winter and spring in suggesting the elements of a national program in space science, and in providing a basis for proposals which were subse-

quently made by the Administration on the organization of a Space Agency. The statement "Introduction to Outer Space," prepared under the aegis of the Science Advisory Committee, was issued by the President as a formal paper, published under the imprint of the White House. This statement has had a circulation running into the millions.

Fourth, the Panel on Research Policy has been examining the conduct of research and the use of science by government, especially the government's methods for formulating policy and achieving coordination in this field. The close coupling which now exists between the policies, administrative actions, and budgetary management of the Federal Government and the stability and quality of the total national scientific effort is the most striking and fateful aspect of the nation's science program today. A perturbation in the Federal Government's research program now causes perturbations through the whole domain of American science.

While searching for ways to improve public management where it relates to science, the Research Panel is also giving attention to the nurturing of important new scientific fields and the strengthening of those which are assuming new importance. Meteorology is one example where additional capital funds and emphasis are necessary. Geology, geophysics, oceanography, radio astronomy, studies of the upper atmosphere, combustion, are other examples where augmented support and effort are clearly needed.

Let me note also some other aspects of our national research policy and procedure which have been under study by this panel. Recent estimates of expenditures for research and development indicate that more than ten billion dollars is being spent annually by industry and government, universities, and other nonprofit institutions on research and *development*. This represents a phenomenal increase during the past decade, and we can rejoice in this impressive record of growth, provided we understand what we are rejoicing about. Dollars spent do not necessarily measure results achieved. By far the major part of the ten billion dollars is expended for development, and over the past decade there has not

been a comparable increase in basic research. While our means and methods of measuring research effort and discriminating between basic and applied research are by no means as refined as they should be, nevertheless there is clear evidence that basic research is still underemphasized and undersupported. As the 1957 report of the National Science Foundation concluded: "Economic incentives assure the immediate future of applied research and development." However, these incentives do not have direct and immediate impact on basic research, and redoubled efforts are required if it is to keep pace with the rising demands of technology.

The need, relatively, for more basic research drives to the heart of the qualitative problem we face. Our great effort in the field of development can be made more useful and productive if it can be enriched by the vitamins of basic research activity of greater scope and higher quality than we now support. The situation is not unlike that which has obtained in education. We have done a fine job in educating large numbers while, relatively, neglecting the education of our most talented and intellectually gifted. In both education and research we now face the necessity of emphasizing quality and depth as never before. In research the first requirement to achieve this augmented quality is to do more and better work at the basic research end of the spectrum. I believe without qualification that more first-rate work is now done in the sciences in the United States than in any country of the world. Our deficiency is at the very top, in the area over and above the first-rate, where the great intellectual breakthroughs occur, where the great concepts and discoveries originate that appear only a few times in each century. By heightening and broadening our efforts in basic, uncommitted research, we provide the best possible opportunity to bring about these achievements at the very top and to grow the great men who will fructify and advance all of our efforts, both pure and applied.

As I look at the total spectrum of our research and development effort, I see deficiencies also in the area between basic research and development, the area that is sometimes called sup-

porting research or component development or engineering research. After observing many research and development programs, I am sure that we would avoid costly mistakes in hardware development if we saw to it that the supporting research was done more thoroughly. As the head of one of our great companies recently observed, "The cost of development is far greater than the cost of research, and if a big development gets off on the wrong foot the price is terribly high."

We have reached the degree of maturity in our industrial and technological development where we can no longer depend upon development—upon practical and empirical methods alone; we must give the most careful thought to achieving a proper distribution of effort over the whole spectrum of research and development.

In saying that we need more and better supporting or engineering research, I am also saying that we need to strengthen our engineering. Engineering has a pivotal responsibility in our total technological effort, and, as this effort becomes more sophisticated, we need to draw more heavily on science; we must have engineering education and practice equal to this new and more demanding complexity. We need more engineering research in our engineering schools, not only because we need more research, but because we need more engineers nurtured in the atmosphere of research.

One cannot discuss our national research effort, even when focussed on its economic impact, without giving attention to our changing organization pattern for conducting research. We have come to think of basic research as finding its natural home in the university, and, indeed, the university seems to be the best instrument for conducting basic research. This has not always been true, and we may well be entering a period when other forms of organization will compete with the university in the field of basic research. A few great industrial laboratories have strong basic research programs and an increasing number of government-operated or government-sponsored laboratories conduct basic research, as indeed they should and must.

Recognizing that other nonuniversity organizations have a compelling need to enter the basic research field, we nevertheless need to give careful attention to the overall pattern of our basic research effort. Research is an essential part of the effort of a university because the education of scientists must be carried on in an atmosphere of research and through their participation in research activities. If basic research moved out of the universities, we would certainly reduce our capacity to educate future scientists. Indeed, as Dr. James B. Conant has pointed out, every time we remove a scientist doing basic research from a university, we reduce our capability to train future scientists. As we extend our total national program of research we need to keep clearly in mind the importance of basic research to the educational strength of our universities and make sure that we do not create a pattern which tends, over the long pull, to attract basic research away from the universities.

However, we must also recognize that our research needs are going to require special kinds of institutions separate from the universities. This comes about largely because of the magnitude of equipment and facilities required for much of modern research. The great particle accelerators required by nuclear physics are reaching such size and cost that they no longer can be financed by a university or limited in their use to a single institution. This is becoming true in other fields. In a recent report by the National Academy of Sciences Committee on Meteorology on needs for research and education in meteorology, it urged the establishment of a National Institute of Atmospheric Research which could provide the research facilities on a scale required to cope with the global nature of the meteorological problem as described in this report. These facilities would include: ". . . modern scientific and technological tools such as a large-scale, high-speed electronic computer, a meteorological flight squadron, a laboratory for fundamental research on techniques for probing the atmosphere by electromagnetic radiation, and a laboratory for fundamental research on the use of satellites and rockets as probes of the atmosphere." As en-

visioned, such an institute might be sponsored by a group of universities and would offer opportunities to university scientists and graduate students, but it would be an autonomous institution standing separate from any single educational institution and planned to serve all institutions responsible for research and education in meteorology. Other examples could be cited where we need to find new institutional patterns and relationships to provide research facilities adequate to deal with modern research techniques but too expensive to be confined to a single institution. We must develop the counterparts of the research institutes in Germany and the U.S.S.R., but we must do it by properly relating them to our universities and thus avoid a serious weakness in the foreign institutes.

It is also increasingly clear that, within institutions, it is going to be necessary to create research groups of a size sufficiently large to be effective in achieving an integrated approach to certain complex scientific and technological problems. We need to think of how we can establish institutes within educational institutions which make possible a multiple-discipline attack on a problem. These regroupings and consolidations of research activities bring special problems of finance and organization that will require careful attention at the national level in the years ahead. The need for such integrated groups of sufficient size and scope to tackle many of our problems in science and technology effectively should never, however, overshadow the importance of the individual scientist who is working alone or in a small group. He needs to be afforded the opportunity to work in this fashion, and we must find ways to ensure him freedom to do so as well as adequate support. It sometimes proves easier to get support for a project for a large laboratory than it does for the individual scientist working independently with his own graduate students.

Fifth, the Panel on Science and Engineering Education is now completing a study which is aimed at clarifying and highlighting the nature, the aims, and the needs of that part of our educational system which has the responsibility of achieving a high degree of

scientific literacy in the United States and the stimulation and preparation of adequate numbers of first-rate scientists and engineers. The study is addressed particularly to our national needs for more advanced and more fundamental education for engineers.

These five examples of the many panel activities of the President's Science Advisory Committee, as you will note, are outside of the defense area and bear testimony that a great deal of the attention and work of our panels are concerned with civilian science and technology. At the same time, the committee and my office are working on urgent problems related to defense. This will continue.

III

I have selected these five examples of our work to emphasize our conviction that we must move on a very broad front to make certain that U.S. science and technology match the growing needs of the nation. The needs of the U.S. require us, for the first time except when we were at war, to bring our total scientific and technological effort up to concert pitch. This means unremitting effort to strengthen education, to marshall the technical resources of the free world, to improve and speed communication among scientists, and to achieve new levels of competence and foresight in the public management of our science and technology and its subtle uses in policy making. It means that our defense technology be bold, imaginative, and advanced, and that our civilian science always have before it the incentive of excellence, the reassurance of stability, and the freedom and ardor to adventure joyously. These are the requirements to survive in the technological contest ahead.

THE RESEARCH CHEMIST LOOKS AT SUPERVISION

A panel discussion by members of the Research Center, Hercules Powder Company, Wilmington, Delaware, presented at a session on October 20, 1958 on the theme, "The Research Supervisor," at the Fall Meeting of the Industrial Research Institute at Washington, D.C. In order to preserve the freshness of that oral presentation, the point-of-view and conversational tone of the original text have not been changed.

INTRODUCTION

PETER VAN WYCK
Director, Research Center

The panel discussion, "The Research Chemist Looks at Supervision," was originally presented before a meeting of supervisory personnel of the Hercules Research Center in March 1958.

As in many other organizations, our supervisory staff had engaged in many discussions, both formal and informal, on how best to implement and improve the effectiveness of our research organization. The broad areas of environmental factors and supervisory responsibilities were, of course, considered. But we felt that a fresh point of view—that of the research chemist himself— would be of value.

With this in mind, I approached seven of our research chemists and asked them to present their views to our supervisory staff.

This group of "Young Turks," as I referred to them at that time, represent a diversity of training, experience, and interests. The following discussion, which they have prepared completely on their own, is essentially the same as that presented to the Hercules staff last March.

THE GROWTH PROCESS

Maturity or Just Old Age?

DWIGHT C. LINCOLN
Central Research Division

The subject for this discussion has been announced as "The Research Chemist Looks at Supervision." Perhaps this deserves a little clarification. "Research Chemist"—that's us. "Supervision"—well, let's make that a little more inclusive and just say "management"—that's you. This is clear enough, but the frame of reference is not quite so obvious.

Many organizations, in recent years, have become greatly concerned with the subject of growth. The concern of our group here is with a particular aspect of growth—and we think one of the more important aspects—growth of the individual. It seems almost axiomatic that the research function grows as the individual grows—that the rate of growth and the level of achievement attained depend on the individuals who make up the organization. This makes a consideration of individual growth fundamental to many other considerations.

We plan to inquire into the nature of individual growth, to examine some of the factors of environment which appear to be necessary to growth, and perhaps, in certain instances, to indicate means for promoting this growth. We do not pretend to have the final answers. Our primary aim is to stimulate thought and discussion. From these, some conclusions may arise which will lead to improved courses of action.

Let's define some terms. When we speak of growth of a research organization as a whole we are not concerned with items of physical growth—larger staff, larger budget, greater slice of the sales dollar—as important as these things are. What we are concerned with is growth in function or the ability to do the job better. In terms of the individual, this means gaining in maturity and, in particular, maturing along those lines which can be of most value to the company.

We are not advocating the stereotyped "organization scientist"; on the contrary, individual growth must be considered on an individual basis.

There are two sides to this question of individual growth. From the point of view of the company, what is wanted is maturity, the ability to do a better job and make more money for the company; this is fairly simple. From the point of view of the chemist, what is wanted is maturity, the ability to do a better job and make more money for the chemist. This is not quite so simple. Other factors are also important, factors such as growth in stature, more money, higher position, more money, greater personal achievement, more money, and so on.

These are just two ways of looking at the same thing, however, and there is really no conflict at all. We might construct two hypothetical, extreme cases. First, a staff of high-salaried chemists each with a fancy-sounding title, whose philosophy is "Don't ask questions; do as you are told." The second, a staff of very mature, highly competent, and creative chemists, who are poorly rewarded and have nothing to look forward to. The actual state of the system will always be somewhere in between. Any emphasis of one over the other represents a metastable state.

I would like to illustrate a trend in industrial research by reference to our present group. We have been billed on the marquee outside as the "Young Turks." Young? We have been in industrial research, on the average, for over eight years, and we don't really feel so young anymore. But, historically, the "Young Turks" were not really young either. They were simply a group

which was not satisfied with the *status quo* and took steps to change it. What's wrong with the *status quo* in an industrial research organization? Simply that growth demands change. If growth is deemed desirable, then change must not be resisted; it must not merely be passively accepted; it must be intelligently and consciously directed. We hope that today's discussion may suggest some lines for this direction.

The "Young Turks" were called "young" because they were innovators. But let me suggest another usage of this word, "young"—young by comparison. How many research men with 10 to 20 years of service consider themselves "young" with respect to the company and their research activities? Our guess is that there are not many. An organization which is undergoing rapid physical growth has no problem of men maturing beyond their jobs. However, in many research organizations, during the last decade, the number of technical men in the higher age brackets has increased markedly. Thus, managements of these organizations are forced to view many 10- and 15-year men as "young" simply because there is no provision in the organization for their recognition or, in other words, because the organization itself has not matured rapidly enough to accommodate maturity in its research staff. The word "young," even though applied to a mature research man, implies immaturity. So we come squarely up against a dilemma—the organization wants top-notch mature research men, but it is not likely to be able to develop and retain them unless it can offer something more tangible than perpetual "youth."

In this discussion, we consider growth in maturity and growth in stature, position, etc., as absolutely inseparable.

The ultimate responsibility for growth rests with the individual himself. He must maintain technical competence by keeping up with developments in his field; he must continue to learn and to broaden his outlook, especially toward a better understanding of company aims and problems; he must decide his own goals and work toward them with enthusiasm.

The primary responsibility, however, lies with management. By the nature of the requirements for the Ph.D. degree, an individual with a Ph.D. has largely met the requirements for individual responsibility when he is hired. The desire to grow is innate, but successful growth requires the proper environment.

A new chemist in a research organization does not immediately identify his own interests with those of the company. He probably has feelings of uncertainty or insecurity. His reaction to this new environment may take many forms, from antagonism to passivity. There is also the well-recognized barrier between academic and industrial research. Only management can furnish the energy of activation necessary to surmount this barrier. Thus, it is the responsibility of management to provide the sort of environment which speeds adaptation of new chemists and promotes the maturing process in older chemists.

Since no two individuals have identical requirements, the job of maintaining a near-optimum environment in each case becomes *primarily* that of the immediate supervisor. I say "primarily" because the responsibility obviously extends beyond the first line of supervision. In the subsequent discussion of what are considered important factors in this environment, emphasis will be put on the relationship between the research man and his immediate supervisor.

Our discussion has been broken up rather arbitrarily to fit the group. Ed Vandenberg has prepared a discussion on the general topic of incentives—Why should a chemist grow? Leo Filar will discuss encouragement and challenge and will outline some of the characteristics which we feel any successful supervisor must have. Bob Levering will discuss communications and its importance to the average chemist. Jack Floyd has a few suggestions on training, both as applied to new men and to the "young" older men. Bob Goddu will discuss the general subject of freedom and has an interesting new concept on that well-worried subject. Each topic should take about five minutes time, after which John Walker will

present a brief summary of the main topics covered. We hope that this can serve as a guide to subsequent discussion.

Some of you may have the feeling that all this is old hat, I've heard it all before, and it doesn't apply to me, anyway. Well, maybe it is, maybe you have, and maybe it doesn't; but here's a little test you can make. Ask yourself the question, "Do I have in my organization any research man who I think is not showing the proper growth?" If your answer is yes, then listen carefully, because it does apply to you.

INCENTIVES

Key to Progress

E. J. VANDENBERG
Central Research Division

Incentives represent one of the most important factors influencing individual growth. Needless to say, there are many and varied personal incentive factors. However, since management has little direct influence on these (except at the time of hiring people), we shall limit our attention to those incentive factors over which management has some control.

Certainly management can make it quite evident that there are specific rewards for any productive, growing individual. The obvious reward is by advancement into a position of increasing responsibility, prestige, title, and salary. The time-honored method has been by advancement into administrative channels. In recent years, another path of advancement has become available—the so-called "parallel research ladder," where appointments have been made to research positions of increasing independence, responsibility, prestige, and salary. In our organization, such advanced research positions have the titles, Senior Research Chem-

ist and Research Associate. Selecting outstanding men of demonstrated ability and productivity for these appointments goes a long way toward making it evident that these rewards are open to deserving, growing individuals.

The limitation on the number of available administrative positions is a logical one and is determined by the number of areas or groups to be administered. A similar limitation on the advanced research positions, however, would be artificial. No arbitrary ratio of advanced research positions to administrative positions is reasonable. The only real limitation on the number of advanced research positions should be the relative ability and qualifications of the research men.

A clear-cut knowledge of what salary and bonus recognition a growing research man can expect is important—particularly as compared with the man who just gets by. In other words, are financial rewards really commensurate with an individual's contributions? Each man should be given adequate information about what his financial horizons are and how he may expect to attain them instead of getting this information in dribbles and drabs from varied sources over the years. This is a continuing management responsibility—at initial employment and throughout a man's career.

In particular, the rumor mill is not a very satisfying source for this vital salary and bonus information. The best way to allay rumors is to present facts. Would it not be advisable to show each man a chart relating salary with years of service for various job classifications? Such a chart should point out the spread between just-get-by performance and superior performance. Some may argue that a man should know only the salary range for his job or for those of lower salary. However, for incentive purposes, information on higher salary classifications appears important. Should not more detailed information be given each man on bonus possibilities? What determines his bonus? How does it relate to performance, service, job classification, etc.? Such information is minimal for the true incentive value of a bonus system. Since

salary and bonus are such important incentives, it would seem no more than good advertising on the part of management to provide more adequate dissemination of this information.

Publications represent another important incentive factor. They afford the research man some measure of recognition in the scientific world. Such recognition is all too frequently not available to the industrial research man. In many cases this is due to oversecretive or overcautious company policies. Although it is realized that what can be done in this direction is somewhat limited, it is important that publications be permitted, and indeed encouraged, wherever possible.

Attendance at scientific meetings affords another important stimulus to the research man. In most cases this represents his only personal contact with the rest of the scientific world and enables him to keep abreast of developments in areas of interest to him and to the company. This can be invaluable in stimulating creativity. The research man should participate in the decision as to what meetings he attends. Needless to say, the growing and productive research man must be allowed greater latitude, with regard to both type and frequency of meeting attendance. A liberal and flexible policy in this regard is important.

Many other incentive factors, some of which are less tangible, are important to the research man's attitude, creativity, and productivity. Some of these are the following:

(*1*) A working environment where the man feels he is truly a "member of the team"—where he is in on decisions, in on important conferences, has some contact with management above his direct supervision, is kept closely advised on company policy and decisions.

(*2*) An interesting and challenging research project.

(*3*) Genuine interest in his day-to-day, as well as long-range progress.

(*4*) A "pat on the back" for a good job.

(*5*) Adequate help and facilities.

(*6*) Not too much red tape.
(*7*) Treatment as a mature individual.

Some of these are little day-to-day factors which, nevertheless, can be quite important toward helping (or impeding) a man's development.

A continuing and determined effort by management is necessary to improve some of these incentive factors. It is realized that many of the policies and practices under which we work of necessity represent compromises. Thus, in many categories, progress will be made only by a continuing re-examination of some of these compromises.

ENCOURAGEMENT AND CHALLENGE

Use Talents Wisely

LEO J. FILAR
Naval Stores Research Division

Just as the supervisor has the right to expect certain things of the chemist, the chemist has the right to expect certain things of the supervisor. One of the things the research man, particularly the newly employed one, has a right to expect is help in achieving professional growth and maturity. Because of the inherent closeness in their relationship, the supervisor is in an advantageous position to offer this help, although he does not always do so. He certainly can never do so unless he, as the leader, establishes with a new man a relationship which is on an equal professional level and establishes a feeling of mutual respect and understanding.

One of the ways in which the supervisor can help the new man to grow is to offer both encouragement and challenge. Encouragement is particularly necessary in the treatment of new ideas. Whether in exploratory research or in process development, new

ideas are tender things and need to be nurtured in their infancy. Although any idea will need to survive the "hard-boiled" attitude at some time, too early an application of the hard-boiled treatment will kill almost any infant idea. The supervisor, then, needs to exercise good judgment in assessing the probable worth of an idea at its inception. This good judgment, it is recognized, might well dictate that the idea be nipped in the bud, but what the chemist expects is that the supervisor show a positive rather than a negative attitude. The research man expects the supervisor, as a leader, to:

(*1*) Be receptive. The chemist should be able to feel that his suggestions will be welcomed and treated in a courteous and impartial manner. The rapport should be such that the chemist shouldn't hesitate to use the supervisor as a sounding board for the wildest-sounding sort of suggestion.

(*2*) Act as a consultant. The supervisor should be sufficiently broad in his knowledge of chemistry to be able to discuss ideas in the formative stage. He should be able to offer constructive criticism, suggest modes of action, possible alternative procedures, etc.

(*3*) Show enthusiasm. This is really the exemplification of a positive rather than a negative attitude.

Another manner in which the supervisor can help the chemist to grow and to mature is in the nature of his assignments. A man qualified to do research wants a job which is a challenge and which taxes his ability and ingenuity. There are a certain number of routine, uninspiring jobs which must be handled, but, whenever possible, these jobs should be assigned to people of lesser training. The chemist wants a change, but the supervisor should be aware of the effects of sudden changes. A kineticist might well benefit from a stint at organic synthesis, but the supervisor should not expect him to have the same proficiency from the beginning that he would show if given another problem in kinetics. Above all, the research man does not want to be pushed too hard. A certain volume of output of high quality is necessary, but the chemist does need some time for contemplation, for reading, for discussion with his fellow

workers. If he is involved in crash programs or other high-pressure jobs for too long, both he and the company will suffer in the long run.

COMMUNICATIONS

A Two-Way Street

D. R. LEVERING
High Pressure Laboratory

In order for any of us to function effectively, it is necessary to understand the environment in which we are working, that is, we should have a grasp of the purposes and aims of the organization of which we are a part. This applies equally to managers, supervisors, and chemists, and implies an exchange of information up and down the line.

Often it seems that this exchange of information, or communications as it is often called, defies the law of gravity—everything goes up but nothing comes down. A situation such as this is directly the fault of first-line supervision and management in general. A question by a supervisor to a research chemist about his work is recognized by all involved as a legitimate one. However, the reverse is not necessarily true. Thus information normally flows upward but the reverse flow requires additional effort on someone's part.

Communications can be divided into two categories: information related to a specific job, and information related to overall company activites.

Under the first category, the chemist should be given as broad a background as possible on the thinking which has gone into the selection of a research project, the goals of the project, and their place within the company structure; this is usually done quite well.

However, the same type of information should be available when a project is terminated; this is not always the case. The chemist is usually a sensible individual and can accept the true reason—be it technical, economic, or political. Anything less is frustrating and can cause loss of faith in management. More than a few foolish ideas circulate as reasons for the death of some project because it has not been given a proper funeral. This is illustrative of the type of job which has to be done in communications. It goes without saying that the chemist should be included in conferences in which decisions affecting his research project are reached.

The second category, information on over-all company activities, can again be divided into two parts: technical information (actual research going on in other divisions) and general company background and goals.

(*a*) In the area of technical information, management personnel, by the nature of their liaison function, have the over-all company picture and can stimulate their men to become acquainted with other research. This can be done by promoting informal discussion at coffee breaks, lunch, etc. The reading of technical newsletters and reports can be encouraged, and the relevance of some of the work explained. In all of this, the chemist should not have to be a detective to find out about work which might be related to his own work. However, being a detective sometimes helps.

(*b*) New ideas for research are only useful to a company when they are in line with the goals of the company and when they fit into the company's ability to use them, for example, an idea on a method of preparing a new drug is not of interest to a steel company. The more quickly a new man becomes acquainted with the type of work each department does, and the sooner the older men are informed of new trends of thinking or changes in the economic picture, the more likely will they be formulating new ideas which fit into the company's future plans. This is overwhelmingly a supervisor's job. He should create a team feeling so that a man is company-oriented, not as an organization man, but intelligently and objectively and, to borrow a phrase from a well known industrial-

ist, to help a man realize that what is good for the company is good for him also.

Much of this whole business of communications is informal and depends upon the people involved. However, some advantages might accrue from more widespread circulation of official pronouncements such as management newsletters and periodic research summaries.

Effective communication can be achieved only by a man who is secure in his position and confident of his own abilities. Also, it should be remembered that what is important in all communication is not what the speaker says and means but what the listener hears and understands.

Thus communication is a two-way street with information flowing *both* ways. The *proper flow* depends upon you.

TRAINING

Catalyst for Growth

JOHN D. FLOYD
Applications Research Division

We all came to work for the company with at least the potential of being able to do industrial research. Most of us wanted and still want a career in this type of research because it allows us to follow our inclination toward scientific investigation, and, at the same time, receive an adequate financial reward for it. If we had wanted to be salesmen or merchandizers, we would have chosen a different discipline for our training. Logically, I think, we anticipate that we will improve in our ability to do research and eventually become good, mature, research chemists from both the company's viewpoint and that of the field in general.

Recently, however, surveys have been made which tell us that this may not be true, that the industrial scientist is generally con-

sidered to be less proficient technically than his academic counterpart. Even if we choose not to believe the results of such surveys, I think the company and the industry are constantly faced with how to get better quality research for the time and money expended for it.

Just as money won't breed genius, upping the research budget and creating a larger staff won't buy better research. We've got to have better research people and we interpret this to mean broader research people, i.e., people who are not only proficient at molecular architecture but who also have some concept of the utility of their structures. This type of individual can't be created overnight; he must be the product of a concentrated, well-planned, training program. This must be done while still maintaining the over-all efficiency of the research function.

Let's start with the new Ph.D. The graduate curriculum provides little or no training in the conversion of laboratory findings into useful products. The new research man is thus unable to make a significant contribution in terms of profit to the company immediately upon graduation. Therefore, a systematic program of training should start with the new employe. He should be given initially the opportunity to work with a mature research chemist or a senior research chemist doing independent research. Through an extended period of close but informal contact, he must be introduced to the company, its raw materials position, its process equipment and technology, any advantageous position of its sales force, and its research philosophy. At the same time he should learn his responsibility to the company and what he can expect for well-planned and executed research. How long should this take? We don't know, it will vary with the individual. We think six months to a year should be long enough for anyone. But the point is, give it to him slowly enough so that he can digest it, but make sure he gets it. This is in contrast to the sink-or-swim technique in training new people which is advantageous for only the rare individual. It is used by management and supervision only because it requires little effort, but it is costly in terms of individual growth

and the over-all research progress. It's obvious to most of us that the new man has to have some orientation, but what about the older man? Does our training stop when the man is properly company-oriented? We think it should not. This man's problems are different but are even more important to company growth. He wants to grow and has been in the research function long enough to know that he can grow by one of two paths, that is, by broadening himself into new fields, or by more intense specialization within a field. Supervision should not only advise him as to which course to follow but should encourage him to take this course. The effective training program for the maturing chemist should thus be broad enough in scope and have enough depth to satisfy the demands of both these paths. There are several mechanisms for making such training practicable. The simplest way is to take advantage of company experts through a program of discussion groups led by our own people, and on company time. This is currently being done, more or less, by some groups, but this approach is not sufficiently active, and the field covered is not sufficiently broad, since the speaker is rarely from outside the particular division sponsoring the discussion. In addition, where it fits into over-all planning, the younger of these chemists should be given the opportunity of working with our top chemists at the bench level. This implies that most of our top chemists are at the bench level, which isn't true, but perhaps it should be because the help that could come from such experience usually comes only after the mistake has been made. Such contact would not only be of technical benefit, but it would again aid in company orientation and responsibility. Another way is to use outside experts more effectively through company sponsored symposia on specific subjects of current interest, including symposia on use technology.

We feel that the promotion of breadth within specialization is very important to individual growth or professional maturity. What we have in mind is aiding the individual to broaden himself to the limit of his chosen field. Perhaps this can best be achieved by a periodic and systematic transfer policy or rotation of assignments

among the groups in a research organization where people can grow into new fields of application by working in them. What we're saying is that possibly our transfer policy within the research function is not active enough and that possibly it breeds the kind of specialization we do not want. Finally, this individual growth can be promoted by special-assignment work. For example, we have an arrangement in which a research chemist is working with a professor at a well-known university on projects of academic, as well as industrial interest. This type of assignment not only broadens the technical background but, if publicized, could be used profitably as an incentive for individual growth.

All of this presupposes the desire of the individual to grow in research. He must, indeed, have this desire before any training program can be effective. The way to ensure this desire is to provide proper inducement and constant challenge to his technical ability, and not to provide cozy little nooks where growth is not a requisite. The responsibility for a favorable growth environment lies with you in research management, and a positive training policy is a very important part of this environment.

FREEDOM

Promoter of New Ideas

ROBERT F. GODDU

Analytical Division

Freedom and free time is a subject much discussed today in research management's philosophical journals. To many chemists, the cry, "10% free time," seems to be as stirring as "taxation without representation." Many people in management, especially those far removed from research, may view free time as "time off" or time which cannot be properly charged to an appropriate, profitable account. What we believe the chemist really wants when he

asks for more freedom is freedom for work, not freedom from work. What we should like to propose is 100% free time and freedom.

Freedom means different things to different people, and there are limitations to most freedom. There are three freedoms which I will discuss very briefly. The extent to which these freedoms are available to the researcher is a direct function of the policy and attitude of management and the supervisor.

1. Freedom to Choose One's Job or Problem

This freedom is somewhat limited, but the supervisor can and should take the wishes and interests, as well as the ability, of the research man into consideration before assigning jobs. When several jobs are to be considered, the supervisor can take the research man into his confidence and give him the opportunity to select his job, within the limits available to him.

2. Freedom Within a Given Job or Problem

Once a research man's job has been chosen and he has been given all available information relative to it, he should have complete freedom as to how the job is tackled. He should be able to feel that his decisions will be backed up by his supervisor and higher management. Since freedom in the choice of a job or problem is often limited, this freedom in how it is handled is of extremely great importance to the research man. Only by encouraging this freedom can supervisors build self-confident, aggressive, research men in their groups.

3. Academic Freedom

This is the freedom which is emphasized so much—freedom to browse, contemplate, and generate new ideas; freedom to explore new fields or re-evaluate old ones; freedom to be a researcher rather than merely a problem solver. It is here that the supervisor

has a real responsibility to see that his men are not pushed so hard that they do not have this time. The idea that the way to make a research man mature is to really pile the work on and let him do the best he can is open to question. Research men undoubtedly age in this atmosphere, but they do not necessarily mature. If men feel as if they are in a shooting gallery where a new duck pops up every time they knock one down, they will seldom take the time to examine the gun they are shooting with, nor will they be able to look around for new and more interesting targets.

What the supervisor and management must do is to see that there is always the opportunity for the chemist to pursue his own particular bent, in spite of the pace of ordinary work. When this opportunity is present, some men will avail themselves of it, others will resist; the latter require and should have more direct stimulation. This may be particularly true of older men who have not matured in a free atmosphere. Also, some men will make more advantageous use of their free time than others, and here, again, the supervisor can encourage those who are most productive. Adequate technical assistance in the laboratory is necessary to give men the time to utilize and exploit this freedom. At present, too many mature men are doing jobs well below their maximum capabilities and are chained to menial tasks at the bench. Freedom has lost in its continual battle with expediency.

Management thus has two primary responsibilities with respect to freedom. The first is to provide continuous opportunities for freedom for the researcher. This is basic. The second is to stimulate and encourage the research man to take advantage of these opportunities. Except in isolated situations, management has not accepted these responsibilities to date.

SUMMARY

JOHN F. WALKER
Synthetics Research Division

As the final speaker, I would like, at the risk of being slightly repetitious, to begin by summarizing what the previous speakers have said. Each speaker has attempted to cover what we consider to be an important area of the topic, "The Research Chemist Looks at Supervision."

To begin with, we directed attention to the growth process in the research man and emphasized the difference between growing older and becoming mature.

Incentives: Salary, Advancement, Physical Environment

We believe there are both specific incentives (salary, advancement, and many others) and nonspecific incentives (physical environment, for example) possible in the research organization. Two areas of emphasis are economic incentives and the knowledge by each individual of where he stands in the organization and where he can hope to go.

Encouragement and Challenge: Supervisor as Leader and Consultant

Encouragement and challenge of the research chemist is best provided by first-line supervision. We expect the supervisor to act as both a research leader and consultant and, furthermore, to be a leader of individuals first and only secondarily of a team.

Communications: Upward and Downward

The importance of good communications to a research organization needs no emphasis. However, we feel that communication

downward is just as important as communication upward. This point applies not only to information specific to a job at hand, but also to company-wide information.

Training: Orientation and Inspiration

The function of training in a research organization is to develop a better and more mature industrial research man. With new men, the problem is one of company orientation and clarification of responsibilities; with older men, the problem is one of keeping abreast of technical advancement and maturing in one's field.

Freedom: For, not From

Freedom is a much-misused word in nearly all areas; this is equally so as it is applied to freedom in research. It is somewhat trite to say that the research chemist prefers freedom for, rather than freedom from, but it is nevertheless true. Freedom in any area is limited by certain restrictions, but generous aspects of freedom should, but in our opinion do not always, apply to the industrial research man in the choice of his assignments, in carrying out these assignments, and in spending his time on work specifically of his own choosing.

The title of our talk is "The Research Chemist Looks at Supervision." We have tried to discover what he is looking for. Our answer is that he is looking for the opportunity for individual growth with all its ramifications, and we add, further, that growth of the research function as a whole is not possible if individual growth is neglected. Furthermore, growth will be accomplished only if the desire to grow is present and if the environment for growth is provided. Research and company management have a large role (in reality the principal role) to play in regard to both these points. We would like to emphasize, however, that the crucial meeting

ground of management and the research chemist is at the level of first-line supervision, and that the personal relationship at this level will often decide the extent or nature of growth in the research chemist. A further point of emphasis is that individual growth is an individual problem which can never be solved by blanket proposals, but only by individual treatment of the people involved.

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THE RESPONSIBILITIES OF THE FIRST LINE OF SUPERVISION IN RESEARCH*

JAMES HILLIER
Vice President, RCA Laboratories
Radio Corporation of America, Princeton, New Jersey

Introduction

As a result of some consideration of different means whereby the Industrial Research Institute could increase its value to its members, it was decided to investigate the value of small discussion groups. Such groups were to have the general objective of establishing the fundamental principles of research management. The validity of this approach was tested by the organization of three experimental study groups, which took "The Responsibilities of the First Line of Supervision in Research" as their topic of discussion. The groups were composed of experienced research executives and were limited to eighteen participants each. In each of the last two groups, five different individuals from the first group were included to provide a more advanced starting point for the discussions. Finally, the participants in the first group (which included ten individuals who had participated in two groups) met to evaluate the concept of study groups and to draw some conclusions relative to

* Paper presented at a session on October 20, 1958 on the theme, "The Research Supervisor," at the Fall Meeting of the Industrial Research Institute at Washington, D.C.

the subject discussed. It was unanimously agreed that the study groups had provided substantial benefits to the participants. In addition, it was agreed that considerable progress had been made toward reaching some understanding of the responsibilities of the first-line supervisor.

This paper has been written as a result of these study-group discussions. Its purpose is to extend their conclusions to provide a general basis for establishing the responsibilities of the first-line supervisor. In this paper, as in the study groups, the first-line supervisor in research will be defined as the man to whom the *professional* worker at the lowest level in a research or development laboratory looks for supervision.

The Study-Group Discussions

The study groups immediately encountered enormous variations in responsibilities, activities, and titles of first-line supervisors in the laboratories represented. In fact, it appeared that each job description was unique to the laboratory in which it originated. For instance, the seventeen laboratories represented in one study group were found to use twelve different titles for the first-line supervisor's position.

The responsibilities of the position were found to be influenced by the nature of the laboratory as expressed by four characterizations, each of which varied for particular laboratories over a range between two extremes. These characterizations were identified as follows.

1. The range from product development to basic research.
2. The range from Government-contract to commercial support.
3. The range from a project type of organization to a functional type of organization.
4. The range from a very formal to a very informal organization.

First-line supervisors in various kinds of laboratories as characterized above were found to range from individuals who have heavy admin-

istrative loads, including scheduling, budgeting, salary administration, and facilities administration, to others who have only a responsibility for technical supervision. There are first-line supervisors who are appointed to the position by formal selection procedures, and there are others who develop into the position by a process of natural selection. The study groups began to suspect that there are no two laboratories in which the first-line supervisors have identical jobs.

This is approximately the level of the conclusions reached by the experimental study groups. In what follows, an attempt will be made to extend these conclusions by providing a more general basis for establishing the responsibilities of the first-line supervisor and for adapting them to specific cases.

Some Basic Considerations

The main thesis to be discussed is that the variations in the responsibilities of the first-line supervisor uncovered by the study groups are merely the results of adapting certain basic principles to the specific commercial and technical climates in which a given laboratory operates. If this thesis is to be valid and useful, it must be possible to develop some basic principles which will stand the test of application to any laboratory.

To do this one must cut through the tangled overgrowth of day-by-day concern with facilities, budgets, organization charts, personnel, and technical problems, and determine what a laboratory management is really trying to do. The term "laboratory management" will be used to describe the entire management team, *including* the first-line supervisor.

The basic job of laboratory management can be divided into two parts: (1) the "outside job," and (2) the "inside job." Closer inspection shows that the outside job has two parts:

a. Determining research objectives: this is the continuous job of determining what the laboratory should be doing.

b. Transmitting research results to the company: this is the job of ensuring that research results become known within the company so that they may be properly utilized to its profit.

The inside job also has two parts:

a. Introducing the research objectives to the laboratory: this is the continuous job of translating research objectives into research projects and adjusting the research program to accommodate them.

b. Maintaining the productivity of the laboratory.

It will be recognized immediately that the standard procedures of management are implicit in these jobs, but only to the extent that these procedures provide tools or set boundary conditions for the accomplishment of the jobs. It is not expected that there will be any quarrel with these statements. The real problem is how to do these jobs.

It appears possible to carry these basic principles at least one step closer to real problems without losing generality; that is, without having to specify the nature of the laboratory. The responsibility of the first-line supervisor then becomes clearer, and one can begin to understand how to adapt the general responsibilities to optimize them in any particular laboratory.

The two parts of the outside job are obviously problems of two-way human communications. The laboratory management has the responsibility of establishing and maintaining the proper communications network both within the laboratory and between the laboratory and the company. The first-line supervisor is a most important link in this network, since much important information passes through him to and from the productive workers. As part of the laboratory's management, he has a responsibility for maintaining the operation of existing channels of communication and establishing new ones as they are needed in his area. This is perhaps too concise, but so much has been said on the subject of communications that it will not be elaborated further here.

The first part of the inside job obviously is also one of communication. It is closely related to the establishment of the communications network for the outside job and the first-line supervisor is equally important in accomplishing it.

It is in the second part of the inside job that the first-line supervisor appears to have the heaviest responsibility. The successful accomplishment of any research project results principally from the productivity of the bench workers. At the heart of this productivity is their *creativity*. Management's job is to establish and maintain a high level of creativity.

In trying to analyze demonstrated creativity in a laboratory, two key factors are invariably involved—a certain type of individual (the creative type), and an appropriate working environment. Creativity in the technical sense can be nurtured only by the proper combination of these two factors. The spark of creativity cannot kindle a flame if either of the two is deficient. Management's inside job is the selection of creative individuals and the establishment of an environment that maintains their creativity and directs it to the accomplishment of the research objectives.

The Creative Individual

The characteristics of the individual are extremely important relative to his selection as a member of a research organization. Some of the most desirable of these characteristics are discussed below.

1. The individual has a high level of native intelligence. The surveys that have been made indicate that most scientific personnel that we find in research activities have this intelligence. This is a *necessary but not sufficient* condition for creativity.

2. The individual has a complete dedication to and a complete absorption in his field of interest. He has an objective recognition of the needs of his specialty, and these continue to present him with a challenge.

3. The individual's complete immersion in the field is supported with appropriate educational background and experience, regardless of how they have been obtained. It is supplemented by broader interests. He never ceases to learn, but is obviously not the "professional student."

4. The individual has a temperment which keeps him continually dissatisfied with the *status quo*. His dissatisfaction is constructive, in that he always believes there are opportunities for further improvement, even though he may find it difficult to state these explicitly.

5. The individual is highly sensitive to slight departures from the established pattern of his specialty. This is perhaps really a summation of a number of the previously stated characteristics. It makes the assumption that he has such a thorough knowledge of his specialty that he has been able to establish its basic principles in their simplest form. This provides quick reference for all the varied observations he makes in the course of his work. The slightest discrepancy with his simplified understanding of these basic principles then becomes a clue which may lead him to a new discovery or to an advance in his field.

The Creative Environment

Having selected the creative individual, it is next necessary to provide a favorable environment for him. The following is a list of some of the factors which appear to be important and which form the basis for the management policies within many laboratories.

1. The creative individual must have freedom of action within his field of interest. Naturally, the process of original selection ensures that the field of interest of the individual is also the field of interest of the company.

2. The continued existence of understood objectives is beneficial to creative thinking. The objectives may be established by the individual or they may be established by the company. In

any case, they must be realistic objectives which the individual understands and with which he agrees. The good research man is most sensitive to artificial or unrealistic objectives, and they should be avoided.

3. There should be inherent in the environment a certain degree of pressure toward accomplishments. The pressure should be a natural one. While it may be applied by management, it must be understood by the individual and must be recognized by him as valid. It seems to be extremely important not to carry pressure to the point where the individual has no time for some constructive daydreaming. (Perhaps this is an area which could do with greater appreciation in the management field.)

4. The environment should be one in which there is a high level of activity. A continuing stream of accomplishments in the environment appears to be highly stimulating to the individual.

5. There must be an assurance of recognition for any valuable contributions the research man makes—by the individual's professional associates, both within the company and within the professional societies of which he is a member, and certainly by his superiors. A policy of early publication is one very important way of ensuring this.

6. The environment should obviously include the presence of stimulating associates, both within the company and among the other professional contacts of the individual. To this should be added the cross-fertilization provided by coupling experimental and theoretical approaches.

7. The environment must emphasize the basic assumption of any laboratory, that opportunities for technical advances are plentiful.

8. The research management must recognize that nonconformity often accompanies creative ability and must be willing to accept and work with the personnel problems that may arise as a result of nonconformity. The creative man continually challenges the interpretations of the rules of nature. The interpretations of man-made rules are even less acceptable without questioning.

9. It is important, in these times, that good facilities be provided along with adequate technical assistance. On the other hand, one must not carry this assistance to the point where the creative individual no longer has an opportunity to profit from the clues which nature often provides during the execution of the more mundane laboratory tasks.

10. Implicit in several of these factors is the assumption that all necessary information—both technical and business information—is easily available to the worker.

The above list is probably not complete, but it does appear to include the major elements which management must maintain in the research environment if the research is to be done efficiently or, for that matter, if it is to be done at all. Here, as in the communications problem, the first-line supervisor is the most sensitive point in the management chain.

Generalized Responsibilities of the First-Line Supervisor

The reasoning in the above paragraphs can now be reviewed to try to reach some conclusions. The first step was to establish the basic responsibilities of research management. These were stated as objectives. These objectives were then translated into two operating problems which are sufficiently basic and generalized to apply regardless of the type of laboratory. These are:

a. The establishment and maintenance of an appropriate communications network.

b. The establishment and maintenance of a creative personnel in a creative environment.

In this translation, the specific management methods, including consideration of schedules, budgets, manpower, and human relations, still provide the working tools and the boundary conditions.

The first-line supervisor plays a key role in handling both of these operating problems. Because of his close association with the

productive research worker, he has a greater direct role in the establishment and maintenance of a creative environment, but obviously his role as a communicator is closely interwoven with it. If the requirements for a creative environment are considered from the point of view of the first-line supervisor, they can be readily translated to a general list of his responsibilities. When this is done, his role as a communicator is also established. The responsibilities of the supervisor that result are the following.

1. To participate in the selection of creative individuals (appropriate for the company's interests).

2. To manage his team to provide maximum freedom of action within existing boundary conditions.

3. To participate in the formulation, interpretation, and acceptance of realistic research objectives (a major communications problem).

4. To maintain appropriate and realistic pressure toward accomplishment.

5. To assure appropriate recognition of contributions made by the individual members of his team.

6. To maintain communication between his group and the other parts of the laboratory and the company to provide knowledge of stimulating activities and to provide association of stimulating individuals.

7. To play an appropriate role in the provision of adequate facilities and technical assistance.

8. To understand and stabilize the personnel problems involving creative individuals.

Conclusion

An attempt has been made to establish a generalized list of responsibilities for the first-line supervisor. This has been done by working from first principles. In this approach, the many variations which occur in the actual positions of first-line supervisors be-

come adaptations of the general responsibilities to the situations in specific laboratories. While this general approach appears to be valid, the details of the qualities of the creative individual, the details of the creative environment, and the detailed responsibilities of the first-line supervisor in research are considered to be only first approximations and susceptible to considerable refinement. The refinement of these lists and the consideration of the principles of adaptation for specific laboratories will be valuable subjects of discussion for future study groups in the Industrial Research Institute and elsewhere.

PROFITS IN SOLAR ENERGY*

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Introduction

Along with addresses and articles on atomic power, intercontinental missiles, space ships, and sputniks, discussions of the potentialities of solar energy are much in vogue. Even as recently as a dozen years ago, serious reviews of research and potentialities in solar energy were scarce indeed. But in the past few years there has been a remarkable advance in the stature of solar energy, and scores of talks on the subject are being presented each year by the dozen or two leaders in this field in the United States and abroad. Many of these presentations appear sadly repetitious to me. I shall attempt to avoid meriting such a criticism as I address myself to the questions of where, when, how, and by whom are profits to be made in solar energy.

Solar-Energy Availability and Characteristics

Before examining the profit possibilities in solar energy, let us take a quick look at this energy source itself. In comparison with practically all of our conventional sources, solar energy is characterized by immense quantity, universal availability, very low concentration, and extreme variability. Its magnitude can be readily

* Paper presented at the Fall meeting of the Industrial Research Institute, Washington, D.C., October 19–22, 1958.

appreciated by comparing the national energy consumption of approximately 15 trillion horsepower hours per year with the annual solar energy received, amounting to 25,000 trillion horsepower hours. The solar-energy supply is thus about 1,700 times as great as our present energy needs. In comparison with world reserves of fossil and nuclear fuels, the solar-energy input is so great that all of the world's known fuels would last only a few days if they were used to produce heat at a rate equal to our solar input. Or, in more easily-visualized quantities, a Texas oil well on a quarter section of land would have to produce crude oil at a perpetual rate of 2,500 barrels per day to have an energy output equal to the sunshine falling on that piece of ground.

Although solar energy is universally received, quantities vary considerably. In the far northern and southern latitudes, the annual input is less than one-fourth of that received in a sunny temperate zone. Besides latitude factors, atmospheric conditions may reduce annual average energy receipt by substantial percentages. Typical annual average radiation intensities in very sunny climates are around 2,000 B.t.u. per day per square foot of ground area. A mean value for the entire United States is approximately 1,500. In London, the annual average is only about 900.

These figures illustrate, also, one of the two major drawbacks in the utilization of solar energy. To convert solar energy to another form for use, some sort of surface must be used to intercept the radiation and convert the radiant energy to another form such as heat, electricity, or chemical compounds. Conventional energy-exchange surfaces, such as the tubes in a boiler furnace, may have hourly heat rates of 100,000 B.t.u./sq. ft. of surface, and seldom would a commercial heat exchanger be operated at heat-transfer rates below several hundred B.t.u. per hour. Solar radiation, however, has a maximum intensity of only about 350 B.t.u. per square foot per hour, and, on the average, in a sunny climate, only about 200 B.t.u. would be available per sunshine hour on each square foot of heat-transfer surface. This means that large surfaces must be used for the recovery of appreciable quantities of energy.

Possibly the most serious drawback in the utilization of solar energy is its intermittent nature. Not only is there the regular and predictable variability from day to night, but there is fluctuation due to cloudiness. Seasonal variability is superimposed on these other fluctuations. The use of solar energy would thus have to depend on there being (*a*) no need for continuous energy supply, or (*b*) supplementary energy availability when solar energy is unavailable, or (*c*) the availability of some form of solar-energy storage. Examples of the first situation are very scarce; in the second situation there is promise of use; and in the third situation there has been considerable use.

Solar and Conventional Energy Sources

In approaching the question of profit in solar energy, it may be helpful to consider the sources of profit in conventional energy supplies. By so doing, we may see more clearly what types of industry should participate in the commercialization of solar energy.

Those firms and individuals who have income from energy may be divided into three groups. First, there are the owners and producers of the basic energy source. These comprise the organizations which own and mine coal and uranium deposits and those who own, discover, produce, and sell petroleum and natural gas. Secondly, there are the organizations which convert the basic energy sources to other forms and sell the resulting energy. These include the petroleum refiner who manufactures motor fuel, furnace oils, and so on, and the utility companies which produce and sell electricity by burning the basic fuels or by using water power. And thirdly, there are the suppliers of materials and equipment which are used by the producers, the converters, and the ultimate users of energy. Included here are the manufacturers of automobiles, electric generating equipment, steam boilers, household furnaces and air conditioners, cook stoves, and the many materials which go into the fabrication of such pieces of equipment.

Let us now see how solar energy might fit into this pattern of organization in the energy industry. At once, it is clear that there is no counterpart of the owner and producer of basic fuel energy. Although land-grabbing on the moon may not be far off, there is not much thought about staking out claims on the sun. So every land owner is in effect a sun owner, in proportion to his acreage. As a result, there appears to be no profit potential in the energy owner and producer category of industry.

Next, in converting solar energy to forms which are saleable, there is not yet but there probably ultimately will be the public utility which will generate electricity from the solar source. The purchase of adequate land and the construction of solar heat-recovery equipment will put the public utility in a position in the solar-energy field entirely analogous to that which it now occupies in the use of fuels for the same purpose. As explained later, however, this is a long-range development of little immediate potential in the United States.

It is in the connection with the supply of materials and equipment for solar-energy conversion that industry can profit from solar energy as it now does from other energy sources. The conversion of solar radiation to heat or to work or to some other form of energy requires facilities analogous to those presently being used in the conversion of energy from other sources. The heating of houses will require solar collectors, heat-storage units, and control systems; these in turn will require metals, glass, plastics, chemicals, and so on. Solar power plants will require the usual power-plant equipment along with special facilities for producing steam from radiation; direct conversion of solar energy to electricity will require semiconductor, alternator, and transformer equipment. Even solar toys involve the producers of materials and equipment.

There are no owners of solar energy, so its use cannot be expected to receive the sort of promotion that natural gas does, for example. Thus one incentive for solar energy development is lacking. In the category of converters and sellers of energy, there is a corresponding lack of incentive to develop solar energy because

there are ample and, in most cases, cheap supplies of fuel and water power for conversion. An alternate basic supply is not yet needed, and the time when it may be needed is too distant to justify research and development expenditures by these organizations now. To some extent, the same might be said of atomic energy, but here there is a heavy government subsidy to the developers of this source which is absent in the case of solar energy.

Since only one out of the three types of industries concerned with energy supply will participate in solar-energy profits in the near future, the probable rate of development of this resource will be largely dependent on the efforts of those manufacturers of energy-conversion equipment and their material suppliers. Research and development will undoubtedly be concentrated among these firms and carried forward at rates dependent on the profit and sales potential of the products. Inasmuch as heat and electricity from a solar source are no different from these energies when derived from conventional fuels, the substitution of solar energy is dependent almost exclusively on economic factors. The ultimate energy derived from solar radiation must be competitive in cost if suppliers of conversion materials and equipment are to sell their products. In the final analysis, then, the rate of solar development by equipment and material suppliers depends on their ability to develop and produce such goods which will make the converted energy competitive with that from conventional sources.

If public utilities will not be using solar-energy equipment for many years to come, who are the buyers for solar conversion equipment? The purchase pattern appears to be largely built around the individual user—the home owner, the business man, the industrial firm, and the farmer. These individuals and groups have solar energy available to them; they will purchase the equipment to convert this energy to useful forms, and they will then utilize the heat, electricity, or other products derived therefrom. Ultimately, the commercial power supplier will also be an equipment customer, but the principal market is, and for some time will be, the individual user of converted solar energy.

What Manufacturers Are Already Profiting From Solar Equipment Sales?

Solar-energy equipment now being manufactured and sold may be conveniently discussed in four principal groups: solar water heaters, solar electric converters or "solar batteries," solar cookers, and toys and novelties. These products are made by numerous manufacturers, who need materials which must, in turn, be supplied by the makers of metals, plastics, glass, and so on.

The manufacture of domestic solar water heaters in Florida has been going on for several decades. Comprising simply a blackened metal sheet, about 50 square feet in area, in contact with tubing through which water circulates and above which one or two glass plates are mounted to reduce heat loss, these roof-mounted units can supply enough warm water for an average household in southern Florida. An insulated storage tank above the solar heat exchanger or "collector" permits gravity circulation to the heating panel and stores hot water for nighttime use. Some systems employ a pump and storage tank below the heater. A recent survey shows no less than a dozen sizable manufacturers of this equipment and that approximately 25,000 solar water heaters are used in this area. Recent developments in insulation, heat-transfer surfaces, and transparent plastic films may stimulate this market considerably.

Almost at the other extreme of size and precision are the solar cells being manufactured for use in radios, clocks, toys, hearing aids, and communication equipment. Although the scientific principle has long been known, a commercial photoelectric device for net electricity production did not appear to be practical until a few years ago, when the Bell Telephone Laboratories developed the silicon cell. This development gave promise because of the much higher efficiency obtainable with the silicon cell than had hitherto been possible with other types.

When a very pure crystal of silicon is sliced into thin wafers which are then "doped" with traces of certain other elements, the semiconductor structure produced results in a current flow when the

wafer is exposed to sunlight. With suitable electrical connections, electricity can be delivered from these cells at an efficiency in excess of 10%. Since the wafers have an area of less than one square inch, many would be required for delivery of much motive-power; but energy for communications and other small power needs can be obtained from a relatively few irradiated cells. The Hoffman solar radio, for example, needs only half a dozen. The satellites this country has launched have radio equipment powered by these solar converters.

At present prices of silicon metal and solar cells, a kilowatt of generating capacity would cost over $50,000. But there are interesting possibilities for substantial cost reductions, such as the use of focusing reflectors to concentrate considerable solar energy onto comparatively few solar cells and the use of less expensive methods for preparing the silicon surface. But even if the solar cell remains an expensive source of kilowatt hours, there will be many new uses for small electrical outputs at these costs. Electricity in space and on the planets may well be produced primarily by converters of this type.

In the third group of products, the solar cooker is beginning to yield profits for the manufacturers of sports equipment. At least three different styles are being commercially made at the present time. The one with which the author is directly concerned is a folding type of solar barbecue grill which focuses the sun on the cooking surface by means of a flexible fabric-plastic reflector supported on a modified umbrella frame. Heat is delivered to the grill at a rate of nearly a kilowatt or about 3000 B.t.u. per hour. Meats can be broiled or barbecued on the Umbroiler in less time than it takes to get charcoal well started, and a camper's sun-heated coffee pot can often be boiling over before his companions can collect firewood. The multi-million-dollar business of the makers of charcoal barbecue units will undoubtedly stimulate further commercialization of solar cooking equipment.

Still another group of solar-energy operated devices are making profits for the manufacturers of toys and novelties. Two examples

are the solar cigarette lighter and the radiometer toy, formerly seen only in optical-store windows. The lighter is a five-inch aluminum dish which concentrates the sun on a cigarette held at the focal point; the revolving pinwheel toy operates by absorbing enough sunlight on the blackened sides of its vanes for them to receive little pushes from heated gas molecules occupying the partially evacuated space in the glass bulb.

The solar-energy equipment now being sold requires a considerable variety of raw materials and auxiliary products. Demands for these are relatively small in comparison with other requirements for glass, metal, plastic films, insulation, fabrics, electronic equipment, and so on. But the present modest scale of commercialization of some of these products is probably only a forerunner of greatly enlarged future markets. Material demands will naturally enlarge as equipment sales grow.

With the exception of solar-electric cells and solar toys, all of the present commercial solar-energy products supply heat. Moreover, the major new applications foreseeable in this century will also utilize solar energy for heat supply. This situation reflects, in part, the technological problems involved in converting solar radiation to mechanical forms of energy.

Another characteristic of these applications is their domestic nature. Since the principal equipment customers are individual families, distribution and selling are important factors in the marketing of solar devices. These activities involve also the sales appeal of the product and advertising. As with many other consumer products, successful solar development may not demand fully competitive energy prices provided that substantial sales effort is put behind the product.

Additional Products with Early Commercialization Prospects

There are three types of solar-energy-operated equipment in the development or testing stages which may soon become items of

commerce. It appears that their application will first be limited to other countries where domestic sources of energy are scarce and expensive or where drinking water is difficult to obtain. These items are a domestic food cooker, a solar-energy-operated food refrigerator, and a small solar distillation unit for demineralizing highly saline water.

Reflecting-type solar cookers of rigid plastic with reflective metallized linings have received field trials in Mexico and in a few other countries where firewood for cooking has become a critical problem. Potentially cheap, these units show promise for substantial sales and use in parts of Mexico, Central and South America, Southern Asia, the Middle East, and North Africa. Tests have shown that these cookers are sturdy, durable, and adaptable to the cooking habits of peoples in many of these areas.

Simple food refrigerators intended for use by peoples in these same regions, often where domestic refrigeration is unknown, are being developed for use in combination with solar cookers. By means of a simple intermittent absorption cycle, several pounds of refrigerant and absorbent in a two-chambered metal container can keep a small insulated "ice-box" cold for 24 hours. The unit must be regenerated once a day by solar heating for about two hours. At a price potentially below $25, the market for such a unit might be in the many millions.

A third need of many persons in the arid, unindustrialized regions of the world is safe drinking water for themselves and for domestic animals. In many areas, highly saline ground water is available but practically unuseable. Other areas, many with high population, are right on the sea coast but lack fresh water even for absolute minimum requirements during certain seasons. Low-cost water distillation equipment would find ready application in these regions, provided that operating energy is available.

Recent improvements on a century-old design, in respect to materials of construction, design, and fabrication technique, show promise of bringing equipment costs down low enough so that, with free solar energy, demineralized sea water and brackish water

can serve these drinking water needs. By evaporation in glass-covered shallow basins directly heated by the sun and condensation on sloping glass covers, distilled water can be produced from sea water in a sunny climate at a daily rate of approximately one-tenth gallon per square foot of basin. This design is now being tested at a pilot plant in Florida, and other units employing transparent plastic films in place of glass are being constructed and tested. As designs are simplified and costs reduced, small installations should begin to appear in areas where water is a most critical problem. As water demands rise and solar-distillation costs are further reduced, markets for the units and their materials of construction should undergo substantial expansion.

The identity of the ultimate marketers of solar distillation equipment is not yet clear. One possibility is that plants will be built in the field by construction contractors, basic materials being purchased for fabrication and assembly at the site. Another possibility is that completely prefabricated units, particularly of the plastic type, will be sold as an item of commerce. This arrangement will probably apply, in any event, for small, family-sized units of a few gallons daily capacity.

Major Future Markets for Solar Energy Equipment

By far the largest markets for solar-energy equipment, at least during the present century, will be for residential heating and cooling systems. One-fourth of the nation's energy consumption is for space heating, and a steadily increasing fraction of electrical output is used for air conditioning. Substitution of solar energy for these uses, even if initially only in the sunnier regions of the country, will require huge quantities of solar heating and cooling equipment.

Residential solar heating is still in the development stage. At least five structures in the United States are now partially heated by solar energy and others are in the planning stage. Several different systems are being used. One employs hot water in a manner

similar to that of the Florida water heaters previously described. Larger solar-energy receivers and hot-water storage tanks are employed. Supplementary heat is being supplied either by conventional furnace equipment or an air-source heat pump. Other systems employing hot air have been built, including that of the author's home in Denver. Here, air is heated by passage between partially blackened glass plates exposed to the sun. Storage is accomplished by passing the hot air through vertical, gravel-filled cylinders in which the air delivers its heat to the rocks. The house is heated by circulating air through the heated rock bed. In still another system, comparatively-low-cost chemicals are used for heat storage by means of their heat of fusion.

The present solar-heated homes in Massachusetts, Colorado, and Arizona and two solar-heated commercial buildings in New Mexico and Arizona are yielding valuable information on equipment performance, architectural design, convenience, economy, and public acceptance. All these factors and others are important.

In areas where domestic fuel is cheap, solar heating will probably not find a significant market in the near future. Elsewhere, particularly where fuel costs are rising rapidly and where sunshine is plentiful, there should be commercial applications within a very few years. Economic factors are not now favorable for the construction of individual solar heating systems, but with volume, factory-production of solar heating equipment, costs should become competitive with fuels in many areas.

The development of solar-powered air-conditioning equipment is considerably behind that of solar heating equipment. No full-scale units are yet in operation. But the appealing aspects of maximum energy availability coincident with maximum cooling demand, seasonally and even almost hourly, along with the rapid growth of domestic air conditioning, are stimulating research in this field. Most attractive are absorption refrigeration systems operated by hot water, air, or steam supplied from roof-mounted solar heat exchangers used also for winter heating. Delivery of heated fluid at temperatures around 200 °F. can readily be accomplished

by the use of existing solar heat-exchanger designs. The technical problems are more formidable than those of the heating system, but the favorable annual load factor on solar equipment operating most of the year is a strong development incentive.

It is very difficult to estimate the potential market for solar heating and cooling equipment. But even if as little as ten to fifteen per cent of new residential construction is provided with solar heating and/or cooling systems, the annual market for perhaps 200,000 units could gross nearly half a billion dollars for the manufacturers of this equipment. Substantial application of solar heating and cooling will also involve other industrial suppliers such as the manufacturers of control equipment, pumps, blowers, motors, and other accessories. Large new markets for glass, metals, heat-exchanger equipment, insulation, and other materials will be established.

Some recent new solar developments may accelerate the rate of domestic application considerably. One of the most significant is the selective radiation surface which, by means of a thin oxide film on a polished metal, yields high absorptivities for solar radiation and low emissivities for thermal (lost) radiation. Other developments are improved plastic films with high strength and long life which could supplement glass in some applications, improved insulation materials, better caulking compounds, and so on.

In an over-all view of residential heating and cooling with solar energy, we can see that (1) these uses represent a large segment of the national energy demand, (2) energy costs are rising and will continue to do so, (3) the quantity of solar energy available in winter and summer in most areas of the country is adequate for most of the house heating and cooling requirements, and (4) the architectural, technical and economic factors can be favorable to this development.

Long-Range Applications

Because of technical as well as economic limitations, several important applications of solar energy appear to be for the future

rather than the present. Commercial electricity from solar energy, for example, appears to be limited primarily by *costs*, at least insofar as presently known methods for conversion are concerned. The efficient capture and storage of solar energy by means of reversible chemical reactions, on the other hand, has not yet been achieved because of *technical* problems.

The conventional approach to electricity from solar energy is by operation of an engine by means of steam produced at the focus of a concentrating solar reflector. These reflectors have various shapes, such as paraboloids, parabolic cylinders, and circular cylinders. Steam has been produced in a small circular boiler, in a long tube at the axis of a parabolic cylinder, and, more recently, in a flattened tube at the focus of a circular cylinder. The high cost of these reflecting surfaces, necessarily moveable to follow the sun, and the very low efficiency of steam engines operating at only moderate pressure have made the fixed cost of the installations per kilowatt-hour generated much greater than the cost of electricity from large conventional power plants.

Another and possibly more promising approach is the vaporization of water or some more volatile liquid in flat-plate solar heat exchangers similar to the units used for house heating. The use of selective radiation surfaces and glass covers treated to minimize reflection enhances these possibilities. But major cost reductions will have to be made before this source of electricity can begin to compete with modern power plants. Again, however, in parts of the world where fuel is very expensive, small electric generating plants operated in this manner should eventually become important. Then, as fuel costs continue to rise elsewhere, and nuclear-energy costs rise also, solar electricity will gradually become predominant.

The other route by which large-scale electric power may be produced from solar energy is by direct conversion with semiconductor materials such as are employed in silicon cells. Economies in materials, manufacture, and utilization will certainly reduce the cost of this type of equipment. Actually, this source of power has much further to go than does the solar-exchanger heat-engine

cycle to meet competition from fuel. With present solar-cell power at a cost about ten times as great as electricity from dry cells, major developments will be needed. These are certainly not out of the realm of possibility.

Another development of major potential in solar electricity generation involves the recent improvements in thermoelectric materials. Although solar heating of thermoelectric elements had previously been tested, power outputs were so low that the method appeared to have very little promise. But the introduction of semi-conductor and insulator-like thermocouples having high thermoelectric power as well as the ability to withstand high temperatures has raised the best heat-to-electricity efficiencies above 10%. With the possibility of even further improvement, the heating of a thermoelectric element at the focus of a solar reflector appears to be a promising technique for electric power generation. Research is therefore proceeding in this area.

These discussions of possibilities for the entry of the public utilities into the production and sale of solar electricity are based on considerations of only the presently known practical sources of energy. If successful and reasonably economical power can be achieved from the nuclear fusion reaction, based on hydrogen or deuterium, commercial solar electricity may be delayed many centuries. Certainly no one is able to make such distant projections, so the best we have been able to do is to outline the expected situation *if* factors preclude application of this vast source of energy.

No solar energy discussion would be complete without mention of the remarkable capabilities of the solar furnace. With very precise focusing reflectors ranging in size from a few feet in diameter to the great 35-foot French solar furnace, these systems can produce temperatures in excess of 5,500 °F. The newest solar-furnace installation is at the Quartermaster Research and Engineering Center in Massachusetts, where a 28-foot-square composite focusing mirror can develop temperatures of 4,000 °F.

Although these units have some unique research and development uses, their cost now prohibits their application as industrial

production equipment. Another long-range prospect, therefore, is that solar furnaces of perhaps more economical design will be widely used for high temperature metallurgical and ceramic processes. Solar variability would of course be a disadvantage, but choice of furnace sites could minimize unplanned shut-downs.

One of the most intriguing potentialities of solar energy is in combined energy absorption and storage by means of photosynthetic chemical reactions. For example, in the presence of certain catalysts, water can be decomposed into hydrogen and oxygen by the absorption of energy in the ultraviolet portion of the solar spectrum. These gases can be stored for subsequent combustion and power generation. Certain other aqueous reactions could possibly be utilized whereby absorption of energy would cause a change in one direction which could then be reversed when desired to liberate the absorbed energy as heat or, more ideally, as electrical energy. Limited progress has been made along some of these lines, but, as yet, efficiencies in converting solar to chemical energy of only small fractions of one per cent have been achieved. If a substantial technical break-through should occur along some such line, the whole economic picture of large-scale solar-energy utilization could be affected. Mechanisms of suitable reactions, a complete understanding of natural photosynthesis, and other basic problems will probably have to be solved before substantial headway is made into practical application of these principles.

This brief discussion of long-range solar-energy possibilities has departed somewhat from the subject of profits in solar energy. At least, these fields do not appear to have profit potential within the next several decades. However, these possibilities should be kept in view so that advantage may be taken of even small steps forward in these and related fields.

Conclusions

In the broad view, solar energy potentially has all the applications of conventional energy sources. There are some considerable

differences in the incentives for development of this new source, the primary responsibility for which will rest with the manufacturers of materials and equipment used in the conversion of energy from one form to another.

Several products are already being made and profitably sold to individual users for converting solar energy to heat and for small electrical applications. Water heaters, cooking units, toys, and solar cells represent this group. On the horizon are several domestic products such as cookers, refrigerators, and water distillers for use in other parts of the world where energy is expensive.

The major profits in solar-energy equipment and materials, as far as the next few decades are concerned, will be in house heating and cooling equipment. In active development now, these applications will take place at an accelerated rate as production economies are achieved and domestic fuels become more costly.

Profits for the converters of energy, that is, the public utilities, in the generation of electricity from solar energy are decades away in the United States. Prior use will undoubtedly occur in areas of the world having less abundant fuels. Photochemical conversion and other long-shot solar applications are research challenges for the future

MAKE-OR-BUY DECISIONS*

MAURICE NELLES
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The way that I have chosen to develop the general subject as to whether to make or buy research and engineering talent, products, or services applies one of the concepts which I use as a check on the completeness of executive decisions. This concept is that the Vice President for Research and Engineering has complete responsibility for the company requirements which necessitated the creation of his office. In a small company the Vice President may be the only man in his division, and he will be responsible for research, development of new products, selection and design of new products, and for all the other responsibilities normally assigned to such a division. As the company grows, or as we apply the concept to larger and larger companies, it becomes imperative that the officer obtain some additional help and, probably, facilities. This necessitates his first make-or-buy decision—should he add someone to his staff to help him with one or all of the functions, or should he have some of this work done by an outside organization? Assuming that we apply the concept to larger companies, it is, of course, necessary for him, from time to time, to employ one or more additional individuals and this, again, requires a make-or-buy decision—should he utilize his own time and talents to search for and evaluate the new executive or manager, or should he utilize the help of an executive search organization? It is true that in a well-

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run, large company there may well be someone in the organization who could be promoted to one of the key positions, and I presume that we should include in our decision-making discussion, at this point, the desirability of promoting someone from within against the desirability of obtaining someone from without. In either case, the executive has to make the decision as to whether he wants to utilize the help of specialists to inform him which is the best to do. When the decision is clear-cut and one-sided and there is no question but that a man who is already in the organization is better than one who can be obtained from the outside for the position, the man should be promoted. Unfortunately, many decisions to promote from within are made without full knowledge of what talent is available from without.

The second broad category in which make-or-buy decisions are important is in the acquisition of equipment, space, apparatus, and specimens. These decisions may involve having a laboratory built by and rented from a financial organization or the making of coffee in the laboratory. The ramifications of the facts which must be assembled and which influence the decisions in cases such as these are so broad and so varied that I doubt we should discuss them here. It has been my experience that, in general, one should tool-up to make about half of the special equipment and specimens which are required for an organization and should arrange for outside production for the other half. I have utilized this criterion in large as well as small companies, and, as a broad rule, it works well. The rule must be changed, of necessity, from time to time, depending upon the facilities available. In time of war or emergency, it is usually wiser to increase the amount of work which you have in your own shop; in times of excess facilities and labor, it is usually economical to decrease the amount of work in your own shop.

The two types of decisions which have been discussed thus far are relatively simple and straightforward. I have heard many say that, if you have the right people and the right equipment and working climate, your worries are over with respect to the function-

ing of your organization. I have never found this to be true. As a matter of fact, I have found quite the opposite. There are organizations which contain outstanding scientists and engineers housed in beautiful laboratories with fine equipment that have been non-productive through the years. This has led me to feel that the most important asset of any technical organization is its program. As I have created significant programs through the years despite resistance, I realize why there are organizations which, after a period of years, do not come up with significant new products and which have spent large sums of money without a proportionally high return on their investment. Sound programs are very difficult to make, and the formulation of programs poses one of the most difficult problems of technical and corporate management.

Last fall I started the work of reinvigorating part of the century-old organization of Crane Co. For many years, this organization was a leader in many fields, including the engineering field, and in the early '30's it was considered to be one of the outstanding engineering organizations and laboratories in the world. Many of the products and processes were ahead of their time. Through the years, the equipment and programs were allowed to deteriorate. After studying the organization and programs for a month, I realized that the most important thing which needed to be done was to obtain important, significant, dynamic programs which, when completed, would result in important, profitable products for the company. It was necessary to obtain programs which would be useful when completed, for I had found that one of the causes for unhappiness was the fact that often products were designed that were never made or sold. There is probably no single act of management that will make an engineer as unhappy as to have him design bridges which will never be crossed. In the case of program development, it is easy to see that what is needed is a dynamic, important group of programs, but it is difficult to obtain and put down in written form the substance of these programs. The manner in which we did this concerned a type of make-or-buy decision which I had not encountered before.

Pefore it is possible to obtain proper programs for product development, it is necessary that broad corporate management be aware of the roles which the officers must play in this activity. It is not possible for the research and engineering organizations to look into a crystal ball in an ivory tower and come up with the answers. It is necessary to have the closest cooperation between the manufacturing, sales and engineering divisions, with substantial help from others in top management. In our organization we have a Product Development Committee which is composed of the Vice Presidents in charge of Manufacturing, Sales, Engineering, and Purchasing and the Assistant to the President, who is concerned with commercial procedures. This group has been appointed by the President, who not only has delegated them the authority but holds them solely responsible for new products as well as for product modification. This group is completely responsible for program development. It has chosen to divide its activities into three main categories, one concerned with plumbing, another concerned with valves and fittings, and the third concerned with air-conditioning. In order to implement the activities of this group, the Engineering Vice President has been made Chairman and his executive assistant has been made Secretary. These two men conduct the meetings of the main committee, as well as the meetings of the groups which are assigned more detailed tasks in connection with the work. Each of the three groups have separate task groups to work on the programs for their respective products. This arrangement works very effectively.

We made the decision to create our own programs in the plumbing field and to obtain help from the outside to create our programs in the valve field. The reason for making the different decisions was that the Henry Dreyfuss organization had been helping our people concerned with plumbing for 17 years and there had been much thinking as to how the programs could be developed. You might consider Henry Dreyfuss as an outsider but he has sat in the inner circles of Crane Co. so long that we consider him as one of us. The main work here was to coordinate our own

activities and thinking and to progress in a rather conventional manner. On the other hand, it was obvious that new thinking was necessary in the case of valves. As a newcomer to Crane, I was bringing in a broader viewpoint and experience in many technical and scientific fields. It is probable that I could have added one or two to the staff and, in the course of six months to a year, could have developed the kind of a program which I would consider effective. On the other hand, if I obtained a special type of help from the outside, I felt that this time could be reduced to two or, at the most, three months. Through the years, one of the organizations with which I have worked on many problems is Arthur D. Little, Inc. I discussed my problem with their president and asked him to assign someone to help me. I indicated that this person should be capable of doing the work of Engineering Vice President in a large corporation, for I wanted someone to help me with the broad planning, and I felt that he should be someone who could take the same type of initiative which I would take and who would work with their organization and also with ours. In this particular case, two such men were made available and, as a result, in less than two months' time, we had a well-rounded, vigorous, important series of programs, and we had reoriented our engineering, research and development activities. Perhaps I should add that one of these men will continue to sit with us in our Product Committee meetings and will continue to help us with our program work.

After a manager has a list of programs which he is eager to work on and finish, the need for more make-or-buy decisions is ever before him. Programs in general have definite goals, and planning how to reach these goals requires make-or-buy decisions. Last April, William McGuigan presented a paper at an Orientation Seminar sponsored by the American Management Association in which he outlined some of the reasons decisions are made to go outside of one's own organization for help. The following is a list of his reasons.

1. To get the right people
2. To get the right facilities
3. For the placement of overflow work
4. To participate in joint projects with other companies
5. To obtain information not available to the company
6. To acquire research management
7. To pursue alternate solutions
8. To check or evaluate in-house research
9. To obtain a critical mass or size
10. To generate data for an industry

There are two additional reasons which are probably extremely important to a research manager. The first of these is economy, in the broadest sense of the word. I do not mean that it is possible to obtain results less expensively by outside organizations than it is in your own organization when the work is in your general field of endeavor. It is more economical in certain instances for us to have an entire program done outside because we could not do it in our own organization immediately and the increase in sales more than compensates us for the increased cost of having it done elsewhere. Another reason for having work done outside is that people can be assigned to a project in fields outside of engineering and research, such as marketing and manufacturing, and thus, with radically new types of projects, can obtain a more accurate result than is possible within your own organization.

Once programs are under way, the technical manager has the problem of when to stop them. In an organization which is very inbred, it is very helpful to have an outside organization look at your programs and determine which should be stopped. This may well be part of the dynamic process of creating and running programs, but I mention it separately because there are still organizations which could function better by making the decision to buy this type of talent. Once a product is developed and completely designed and when the manufacturing drawings have been made, the management of a corporation must still decide whether to make or buy the manufacturing process as well as the selling process. In Crane Co. we buy about one-third of the manufacturing facilities

utilized in making the products which we sell. At the present time, we own and operate most of the facilities and organizations that are used to sell our products.

In summarizing the broad general categories discussed thus far, it is apparent that make-or-buy decisions are important and that they are applicable all along the line of corporate management, including technical-division management. There is a wide variance of opinion as to what the ratio of make to buy should be. My personal feeling is that we should make approximately 75% and should buy approximately 25%. I feel that this applies to the personnel in any given level of management, to the programming, to the facilities, to the services, and to many of the ramifications which confront a corporate officer who has these responsibilities. I realize that there must be many exceptions and that the percentages may vary from time to time, but, as a general rule, I believe this ratio of make to buy results in the healthiest type of operation.

Every manager has to make the decision—where should the necessary talent, facilities or services be acquired? This is one type of decision that requires mature judgment and a thorough understanding of the work to be done and the goals to be reached, as well as the abilities and characteristics of the talent or thing to be purchased. The matching of the two and the maintenance of the proper relationship after the matching is made requires keen executive skill. Mr. McGuigan, in his article, lists some of the questions which one must answer with regard to almost every situation. Those which he lists are as follows:

1. How much work has been done in this field and where?
2. Who is working for my competitors?
3. Am I trying to extend the art or merely to exploit existing know-how?
4. Will proprietary information be needed?
5. Will proprietary information be generated?
6. What about patents?

7. Are we looking for a solution to a specific problem or are we more interested in a basic technique to solve a class problem?
8. Is the subject peculiar to the specific industry?
9. Will industry standards be generated?
10. Will the project be large or small?
11. Will it be a continuing or a short-run effort?
12. Should I buy project management along with the research effort?
13. Will it require special talent or broad-gauge insight?
14. Will it involve special equipment?
15. What is the security level of the findings?
16. What is the cut-off point for this research?
17. What sort of follow-up will be required?
18. Are you going to pay for the entire effort, or are you attempting pump-priming?
19. Will you have a continuing need for outside research of this type?

In addition to the above, I feel that it is very important to ask the following questions.

1. What is the likelihood that the personnel whom you hire to work on this problem will later work on a similar problem for a competitor?

2. What is the probability that, when you conclude the project, you will have succeeded in stimulating the outside organization to spend their own funds to create a patent structure which can be used against you and can cost you large sums and difficulties later?

3. How flexible is the organization, and how nearly will they try to conform to your wishes? For instance, will they insist on writing lengthy reports for which you have no use?

I am sure there are many other, more specific questions which will come up as a result of asking such questions.

There is relatively little difficulty in obtaining a wide variety of research talent to supplement one's own organization. It is very difficult to obtain capable, efficient engineering talent to supplement the work of industrial engineering divisions. Apparently, the romance of research during the past 15 years has attracted many to enter this field. As of today, there is only a handful of organizations that can give the engineering effort of a corporation significant help. Parenthetically, it is interesting that there are many seminars, conferences, institutes, courses, etc., to improve research management. There are almost none to improve engineering management. We are doing something constructive in this regard. I have felt for many years that some university should establish a course for training engineering executives. Very probably this course should take the form of the courses that are given by Harvard University, Chicago University, U.C.L.A., and others to develop general executives. I have discussed this need with many of my friends in universities, and now friends at Pennsylvania State University are interested. The Associate Director of their Ordnance Laboratory and Professor of Engineering is planning to spend two years with our organization. During this time he will be in an executive position and also will attend the University of Chicago Executive Training Course. He then will have the background to help Penn State initiate a course which will be helpful in the development of chief engineers and people who can fill similar positions.

As technical management becomes better understood by Boards of Directors and Presidents, there will be more effective technical management. After the war, it was popular to establish large research organizations, and now they have been in existence long enough to have accomplished much. They are being evaluated, and I am sure many changes will be made. In these, and many other cases, make-or-buy decisions will be considered.

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(signed) ERIC S. PROSKAUER
Publisher

Sworn to and subscribed before me this 18th day of February, 1959.

[Seal]

(signed) Adelaide Rena Prenner
Notary Public
State of New York
County of New York

(My commission expires March 31, 1959)

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